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AIR-BORNE PARTICULATE EMISSIONS FROM COTTON GINNING OPERATIONS

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

1960

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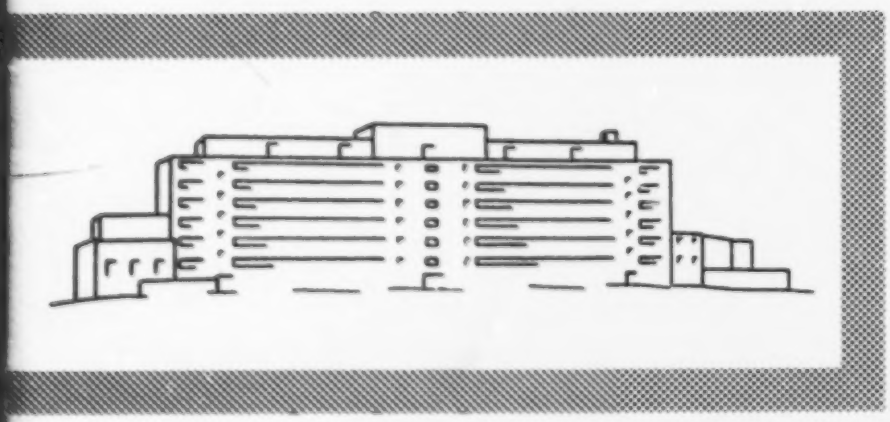

The Robert A. Taft
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TECHNICAL REPORT
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U. S. DEPARTMENT OF HEALTH,
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Public Health Service

AIR-BORNE PARTICULATE EMISSIONS FROM COTTON GINNING OPERATIONS

Prepared by
Engineering Research and Development Unit
Air Pollution Engineering Research

Details of illustrations in
this document may be better
studied on microfiche.

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Bureau of State Services
Division of Engineering Services

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I

INTRODUCTION

Modern cotton ginning installations using pneumatic conveying equipment, air blast cleaning equipment, and seed cotton conditioning equipment have increased the output of normal ginning operations and improved cotton fiber quality. This gain in output has been accompanied by a major increase in the volume of air bearing lint and dust discharged to the atmosphere. The increased proportion of machine-picked cotton supplied to ginning operations has further increased the volume of waste materials. Present day ginning practices may produce up to 1,000 pounds of waste material for each bale of cotton ginned, a significant portion of which will be discharged to the atmosphere.

Although the discharge of waste material to the atmosphere from the individual cotton ginning operation generally results in only a local air pollution problem, the number of such establishments and the gradual urban encroachment into the areas of ginning operations is great enough to warrant consideration of suitable control methods. Figures 1 and 2 indicate the pollution effects and the pollutants involved in the problem. In order to consider possible solutions to these problems, field and laboratory studies of particulate emissions from cotton gins were conducted by the Public Health Service, in cooperation with the Agricultural Research Service.

Figure 1. LOCALIZED POLLUTION PROBLEM

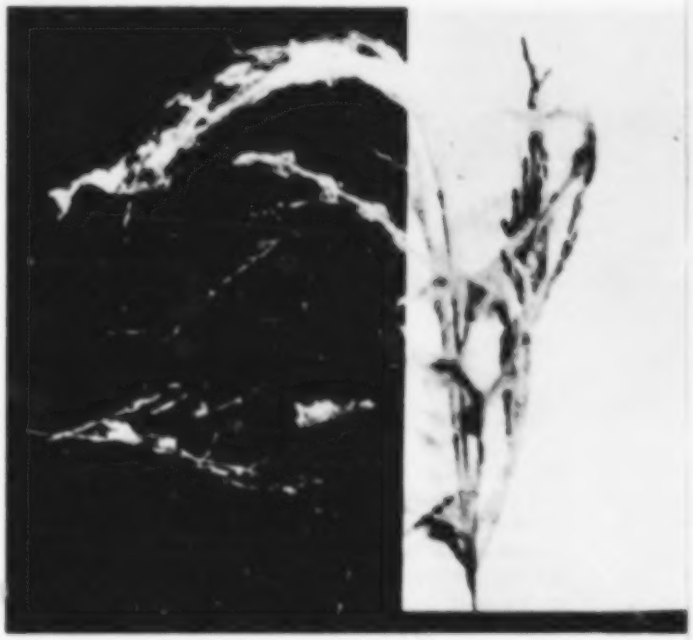


Figure 2. EXAMPLES OF GIN DISCHARGES

OBJECTIVES

The objectives of these studies were threefold: first, to assess the quantity of particulate emissions from cotton ginning operations in terms of its air pollution potential; second, to evaluate the effectiveness of standard laboratory quality evaluation test equipment for predicting these emission values; and third, to develop an economically feasible control technique and suggest control equipment for the reduction of particulate emissions to the atmosphere.

From the standpoint of the air pollution potential of cotton ginning particulate emissions, it is necessary to differentiate portions of the emissions by particle size. Those which are of sufficiently small size to carry beyond the premises of the ginning operations under average weather conditions constitute a local air pollution problem. That portion having a large enough particle size to deposit on the gin premises is a lesser problem. Based on an average wind speed of 10 miles per hour and for particles with a density equal to the average density of particulate emissions from ginning operations, it is assumed in this report that particles 100 microns in diameter and larger will deposit on the premises and that particles smaller than 100 microns will carry beyond the gin premises to the surrounding community.

BACKGROUND

Field sampling of cotton gin effluent and laboratory investigation of procedures for the evaluation of air pollution materials discharged to the atmosphere from the ginning of cotton were conducted at the Cotton Ginning Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Stoneville, Mississippi. The investigation was made at this laboratory, since this operation was considered to be representative of ginning operations in general, and the cotton harvested by both machine-and hand-picked methods and pr `essed during testing was representative of the cotton from the areas in question.

The flow diagram, Figure 3, indicates the following major sources of particulate emissions: unloading fan, six cylinder cleaner, stick and bur machine, gin stand, separator No. 2, seven cylinder cleaner, separator No. 3, and the condenser. The unloading fan, discharge point No. 1, supplies the air for the transfer of cotton from the storage bins or from a wagon to the first separator. These wastes are carried to the dust house by the moving air stream and consist mostly of sand, dirt, and other fine materials.

The cotton then passes from the first separator onto the feed control, into the tower dryer, through a boll trap, and then to the six cylinder cleaner which opens and cleans the boll cotton. The waste discharge from the six cylinder cleaner, discharge point No. 2, is carried to the dust house by a moving air stream and consists of fine particles of leaf trash, dirt, sand, stems, and small sticks. (See Glossary)

From the cleaner the cotton is moved to the stick and bur machine which removes burs, sticks and stems, together with fine trash not removed by the cylinder cleaner. The discharge duct from the stick and bur machine joins with the air discharge duct from the gin stand and wastes from these sources are carried to the dust house, designated as discharge point No. 3. Samples were taken from the combined discharges because individual samples from these two emission sources were unobtainable due to the inaccessibility of the separate ducts.

From the stick and bur machine the cotton passes to a second separator, then to a stub tower dryer, and then to a seven cylinder cleaner. The discharge from the second separator at discharge point No. 4 is emitted directly to the atmosphere outside the building. These wastes, carried through the separator, consisted mainly of fine particles of leaf trash, dirt, sand and stems.

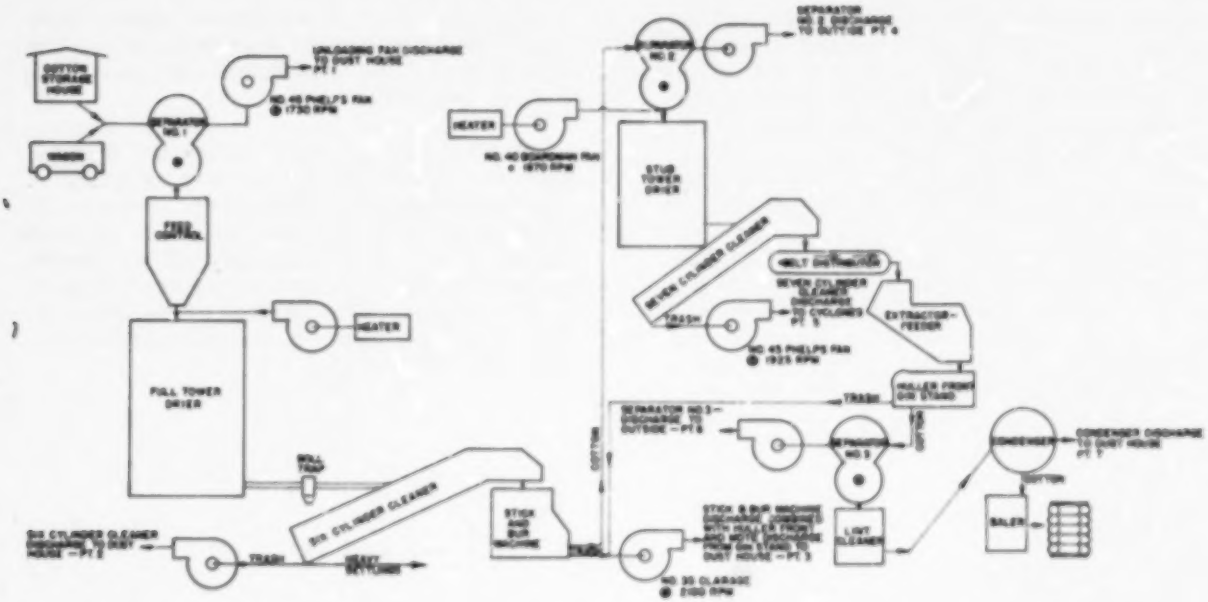


FIGURE 3. FLOW DIAGRAM OF U.S. DEPARTMENT OF AGRICULTURE COTTON GIN, STONEVILLE, MISSISSIPPI

The waste discharge from the seven cylinder cleaner, discharge point No. 5, is carried to cyclones. Tests include the use of either the standard or the alternate (parallel) cyclones. These wastes consist mainly of pin and pepper trash and dirt.

The seed cotton then passes from the seven cylinder cleaner on a belt distributor to the extractor-feeder and then to the huller front gin stand. The trash from the gin stand, burs, sticks, stems, motes, and pin and pepper trash is combined, as previously noted, with the waste discharge from the stick and bur machine and blown to the dust house, discharge point No. 3.

From the gin stand the cotton is transferred first to a separator which removes fine leaf particles, motes, dust, and sticks, which are discharged directly to the atmosphere outside the building, discharge point No. 6. The cotton next travels to the lint cleaner and then to the condenser, which discharges pin and pepper trash to the dust house, discharge point No. 7, then to the baler, and out as a finished product.

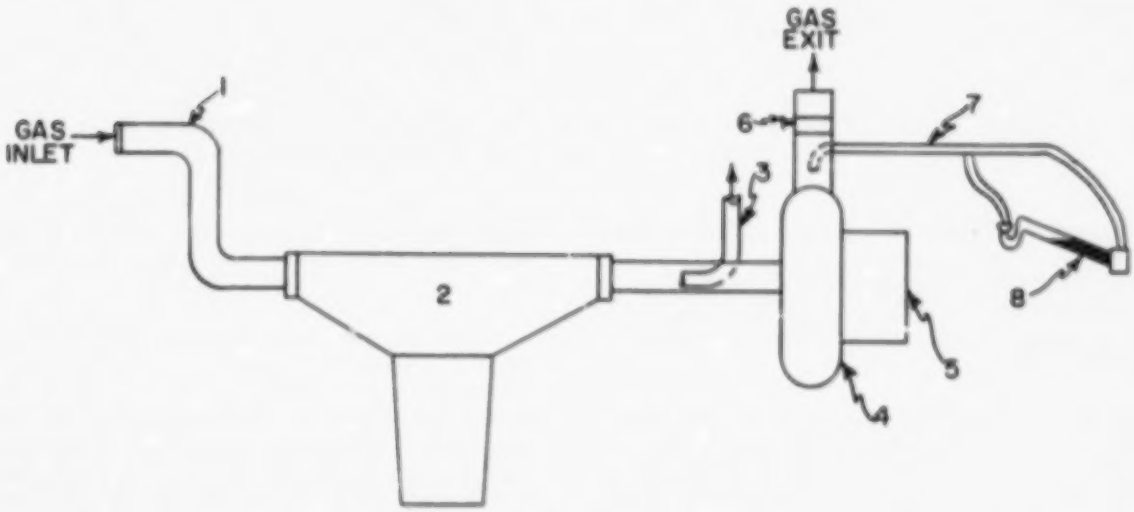
Field Sampling Equipment and Techniques

Initially it was intended to take simultaneous samples at each discharge point to differentiate between total particulate and air pollution particulate emissions to the atmosphere, i.e., particles less than 100 microns in size. Duplicate sampling trains were to be used, with one train preceded by a settling chamber to remove the particulate 100 microns or over in diameter. Due to weather conditions, insufficient cotton was on hand at the Stoneville Laboratory to allow sampling by both techniques at every point of discharge as originally planned. To further conserve cotton, samples were taken simultaneously at two locations for each test. Prelim-

inary evaluations were made at each discharge point to determine those locations containing non-air-pollution particulate, and the settling chamber, Figure 4, was employed at only those emission points. The sampling system, Figure 5, consisted of a sampling probe, a high efficiency cyclone used during high loadings only, a glass-fiber filter, a pump, an orifice flow meter, an integrating bellows gas meter, and various wet- and dry-bulb thermometers.

All points of discharge to the atmosphere were sampled. Whenever possible, sampling positions were selected along straight runs of duct at least 12 pipe diameters in length, and samples were taken at a distance equal to 8 pipe diameters[1] from the start of the run. Where it was necessary to sample ducts not having 12 pipe diameters of straight flow, samples were obtained at a point two-thirds of the longest straight flow distance downstream from a point of gas flow disturbance such as a bend, damper or valve.

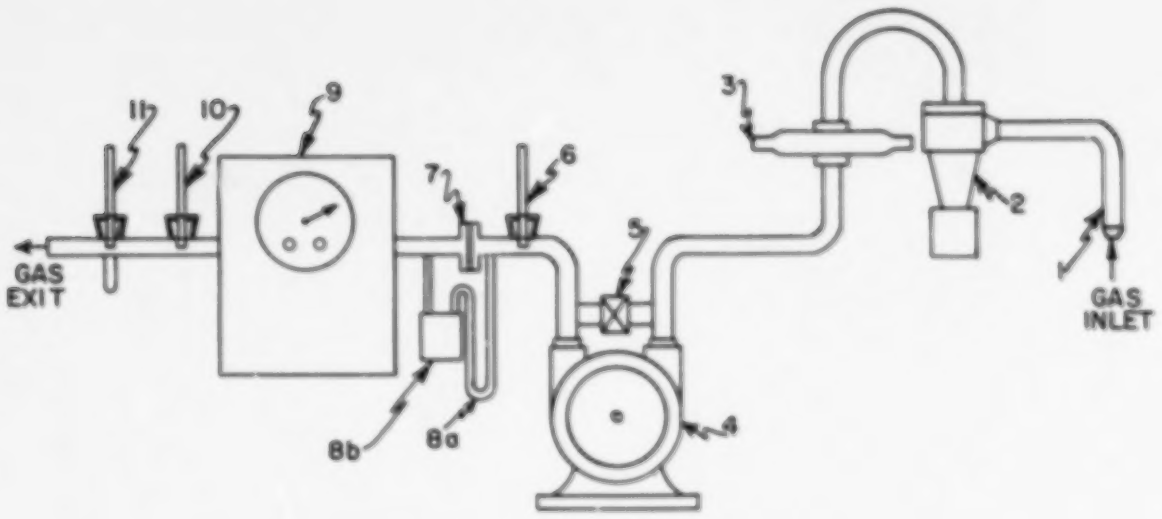
Four to sixteen point sampling traverses were run, when possible, at each sampling point using isokinetic sampling procedures. (1) When the settling chamber was used, the probe was fixed at a point in the duct with a velocity equal to the average velocity through the duct, as it was impossible, because of the bulky nature of the equipment, to move the probe for sampling traverses.



1. SAMPLING PROBE
2. SETTLING CHAMBER
3. PROBE CONNECTED TO SAMPLING SYSTEM NO. 2
4. BLOWER
5. MOTOR
6. FLOW VALVE
7. PITOT TUBE
8. INCLINED MANOMETER

FIGURE 4. SETTLING CHAMBER USED IN CONJUNCTION WITH SAMPLING SYSTEM NO. 2

(1) "Methods for Determination of Velocity, Volume, Dust and Mist Content of Gases", Bulletin WP-50 (5th Ed.,) Western Precipitation Corp., Los Angeles, California.



1. SAMPLING PROBE
2. HIGH EFFICIENCY CYCLONE
3. FIBER-GLASS FILTER & HOLDER
4. PUMP
5. PUMP BYPASS VALVE & LINE
6. DRY BULB THERMOMETER
7. ORIFICE
8a. MANOMETER TO REGISTER
8b. ΔP ACROSS ORIFICE
SURGE BOTTLE
9. BELLOWS GAS METER
10. DRY BULB THERMOMETER
11. WET BULB THERMOMETER

FIGURE 5. SAMPLING SYSTEM NO. 2

Emissions from Ginning Operations

The data on atmospheric emissions, Table 1, are limited in that replicate samples were obtained during ginning of both hand- and machine-picked cotton for only the cyclone discharges. There is, therefore, no indication of the variations at the other points of discharge due to the method of picking. Table 2 presents data on the amount of material collected by the settling chamber and the sampling train, expressed in percent by weight of cotton ginned. Table 3 contains calculated particle discharges to the atmosphere for the total emissions and for the air pollution portion of the emissions, i.e., that portion of the discharged particulates less than 100 microns in diameter.

The evaluation of the particulate emission data from the ginning operation was made, as previously discussed, on two bases: first, on a consideration of the total particulate emission; and, second, on a consideration of only that portion which constitutes a local air pollution problem, i.e., particles of less than 100 microns in diameter.

The data in Table 3 show that the calculated air pollution portion of the total particulate discharge (i.e., particles less than 100 microns in diameter) from the gin to the atmosphere with no air pollution control devices utilized was approximately 7.0 pounds per bale (1.39%) of cotton ginned. However, the gin had installed two types of cyclones on the discharge from the seven cylinder cleaner. One was an 84" diameter standard cyclone with tapered top and bottom sections and the other a pair of 34" diameter high efficiency design operating in parallel. As these cyclones operated with

TABLE 1
SUMMARY OF FIELD DATA
U. S. DEPARTMENT OF AGRICULTURE COTTON GINNING LABORATORY
STONEVILLE, MISSISSIPPI

Sample Point No.	Sample Point Description	Pipe Size	Average Velocity FPM	Volume SCFM	Type Cotton, Picking Method	Samples Collected			Average Emission Rate lbs/hr
						Settling Chamber GR/SCF	Sampling Train GR/SCF	Total GR/SCF	
1	Unloading Fan	16" D	4680	6280	Machine	------	0. 359	0. 359	19.32
2	Six Cylinder Cleaner	16" D	3150	3878	Hand	0. 078	0. 037	0. 115	3.82
3	Stick & Bur Machine Discharge Combined With Huller Front & Mote Discharge from Gin Stand	11" D	4320	2783	Hand	0. 524	0. 026	0. 550	13.12
					Machine	------	0. 065	0. 065	1.82
4	No. 2 Separator	12" D	4450	3260					
5*	Seven Cylinder Cleaner to Cyclones								
5A	Standard Cyclone Inlet*	18" D	4340	7030	Hand Machine	0.0957 0.0957	0.0124 0.0103	0.1081 0.1060	6.51 6.39
5B	Standard Cyclone Outlet*	19-1/4" D	3890	7030	Hand Machine	------ ------	0.0070 0.0150	0.0070 0.0150	0.42 0.90
5C	Alternate Cyclone Inlet*	18" D	4180	6731	Hand Machine	0.0347 0.0346	0.0186 0.0495	0.0533 0.0841	3.08 4.85
5D	Alternate Cyclone Outlet*	14" D	3680	6731	Hand Machine	------ ------	0.0019 0.0054	0.0019 0.0054	0.11 0.31
6	Separator No. 3	21" D	1610	3865	Hand	------	0.0440	0.0440	1.46
7	Condenser	42" D	1240	11523	Hand	------	0.0223	0.0223	2.20

*Either Standard Cyclone or Alternate Cyclone used at any one time; not both together.

TABLE 2. EFFLUENT SUMMARY
(Percent by Weight of Cotton Ginned)

Sample Point No.	Sample Point Description	Settling Chamber (S)	Sampling Train (A)	Total (T)
1	Unloading Fan	-----	0.966	0.966
2	Six Cylinder Cleaner	0.130	0.062	0.192
3	Stick & Bur Machine Discharge Combined With Huller Front & Mote Discharge From Gin Stand	0.625	0.031	0.656
4	Separator No. 2	-----	0.091	0.091
	Seven Cylinder Cleaner To Cyclones			
5A	"Buffalo" Cyclone Inlet	0.289	0.034	0.323
5B	"Buffalo" Cyclone Outlet	-----	0.033	0.033
5C	"A.E.C." Cyclone Inlet	0.100	0.097	0.197
5D	"A.E.C." Cyclone Outlet	-----	0.010	0.010
6	Separator No. 3	-----	0.073	0.073
7	Condenser	-----	0.106	0.106

TABLE 3. ATMOSPHERIC PARTICLE EMISSIONS

Description of Condition	Fractions Under Conditions*	Totals % by Weight of Cotton Ginned	Pounds per bale
A. Total Discharge, No Control	$T_1+T_2+T_3+T_4+\frac{T_{5A}+T_{5C}}{2}+T_6+T_7$	2.34%	11.7
B. Total Discharge, Installed Cyclones in Use	$T_1+T_2+T_3+T_4+\frac{T_{5B}+T_{5D}}{2}+T_6+T_7$	2.11%	10.5
C. Total Discharge of Air Pollution Material (Cyclones not in Use)	$A_1+A_2+A_3+A_4+\frac{A_{5A}+A_{5C}}{2}+A_6+A_7$	1.39%	7.0
D. Total Discharge of Air Pollution Material (Cyclones in Use)	$A_1+A_2+A_3+A_4+\frac{A_{5B}+A_{5D}}{2}+A_6+A_7$	1.35%	6.8

*Note: Code letters refer to data tabulated in Table 2.

efficiencies from 85 to 93% and 95 to 96% respectively, but were applied only to the discharge from the seven cylinder cleaner, the average air pollution discharge to the atmosphere, when these cyclones were being utilized, was 6.8 pounds per bale (1.35%) of cotton ginned. The total particulate discharged to the atmosphere from the ginning operation, when no control equipment was used, was approximately 11.7 pounds per bale (2.34%) of the cotton processed. With the cyclones in use for the seven cylinder cleaner, the total particulate discharge was 10.5 pounds per bale (2.11%) of the cotton ginned. Since the gin sampled was selected as typical of such operations, these values may be assumed to show generally the order of discharges from cotton gins.

Laboratory Quality Evaluation Test Equipment

Two standard laboratory quality evaluation test devices were considered as having potential application in predicting air pollution particulate emissions from the cotton ginning operation. The first of these was the fractionator, Figures 6 and 7. This equipment, normally used to determine the quantity of foreign material contained in cotton, consists essentially of a sheet metal box-like container in which the cotton is agitated by air jets. In the operation of this device, a sample of non-ginned cotton is prepared for fractionation by hand removal of unopened bolls, seeds, and trash. Weights of cotton and removed trash are obtained. The prepared cotton is then placed in the fractionator and a compressed air supply, connected to inlets at the bottom rear of the fractionator, is turned on. The cotton is lifted by the air stream, follows the curved top of the fractionator, drops onto the air discharge slots in the bottom front of the fractionator, and is carried across the bottom to be once again picked up by the air jets, repeating the cycle. The agitation of the cotton by the air stream is continued for a period of ten minutes.

As the cotton is churned by the air stream, the foreign material is dislodged and is carried along with the fractionator effluent. The test equipment used to determine the waste material discharged from the fractionator sampled the entire air flow of the fractionator, and consisted of a settling chamber, a cyclone, and a glass fiber filter which was followed by a high volume blower to eliminate excessive back pressure on the fractionator. After fractionation, the cotton and the fractions collected by the sampling system were weighed to determine the amounts of foreign material removed from the cotton.

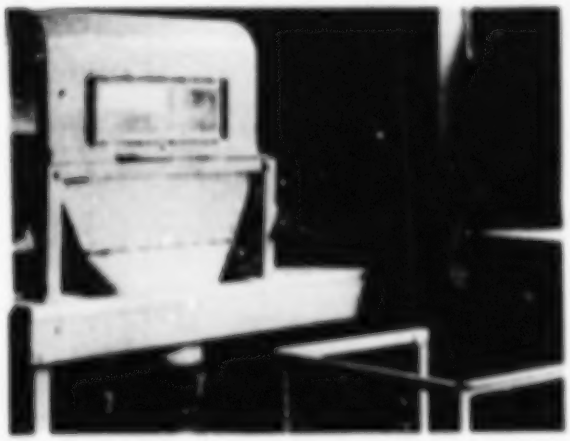


Figure 6. EXTERIOR VIEW OF FRACTIONATOR

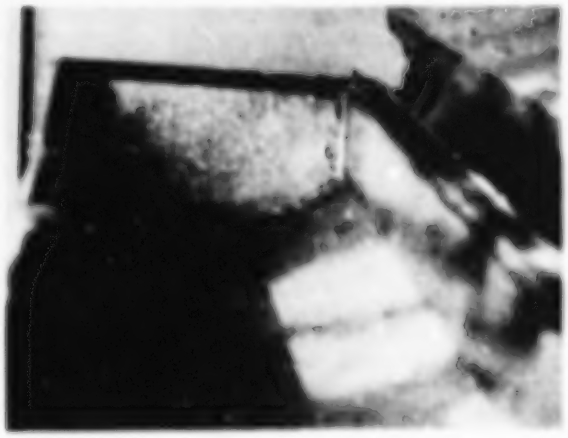


Figure 7. INTERIOR VIEW OF FRACTIONATOR

A second standard laboratory quality evaluation test device used to predict the amount of air pollution particulate emission from cotton gin operations was the Shirley Analyzer, Figure 8. Basically, this equipment is used to determine the amount of foreign material remaining in the clean lint after ginning. Its principle of operation is similar to that of a lint cleaner in that it uses a similar saw arrangement for the removal of foreign material. It is more efficient than lint cleaners in use commercially, but causes a greater loss of usable fibers.

As a method for collecting the fine fraction of the foreign material removed from a cotton sample by the Shirley Analyzer was not available, it was necessary to determine this value by a material balance; that is, the weight of cotton placed in the analyzer must equal the weight of the cleaned sample plus the collected waste material plus the fine fraction quite appropriately designated as noncollected waste. Table 4 contains fractionator sampling train data for cotton obtained from the Stoneville, Mississippi, area. Table 5 contains similar fractionation data on cotton from the Clemson, South Carolina, area. Data obtained from the tests performed by the Shirley Analyzer for cotton from the Stoneville, Mississippi, area are presented in Table 6.

Figure 8. SHIRLEY ANALYZER

TABLE 4. FRACTIONATION DATA ON 20 SEED COTTON SAMPLES FROM THE STONEVILLE, MISSISSIPPI AREA

Sample Number	Large Foreign Material Removed by Hand Before Fractionation	Seed Cotton After Fractionation	Settling Chamber Catch		Cyclone Catch		Material Collected On Filter
			Wet	Dry	Wet	Dry	
	gms	gms	gms	gms	gms	gms	gms
Hand-Picked							
1	0.2	179.0	1.09	.95	1.19	1.07	0.083
2	0.3	206.0	.86	.75	1.82	1.73	0.096
3	0.4	176.0	2.00	1.85	1.44	1.38	0.089
4	0.6	186.0	.77	.70	1.19	1.10	0.055
5	0.2	170.0	.85	.75	1.39	1.30	0.064
6	0.8	171.0	5.32	4.95	1.47	1.42	0.083
7	0.2	159.0	4.92	4.60	1.72	1.61	0.091
8	0.5	171.0	6.88	6.45	1.11	1.06	0.075
9	0.6	170.0	5.35	5.05	2.15	2.02	0.156
10	0.8	172.0	5.01	4.70	1.43	1.37	0.069
Machine-Picked							
11	5.6	169.0	10.83	10.00	.90	.83	0.086
12	8.1	140.0	6.00	5.33	1.45	1.32	0.095
13	5.6	172.0	9.38	8.43	1.85	1.65	0.130
14	4.6	158.0	7.74	6.97	1.82	1.66	0.083
15	4.3	154.0	7.89	7.19	1.55	1.43	0.092
16	9.6	159.0	9.05	8.23	1.55	1.43	0.252
17	7.7	148.0	9.61	8.65	1.24	1.08	0.125
18	7.0	168.0	12.99	11.81	1.43	1.30	0.155
19	10.3	197.0	13.59	12.34	2.10	1.96	0.220
20	6.2	150.0	9.75	8.88	1.20	1.10	0.127

TABLE 5
FRACTIONATION DATA ON 20 SEED COTTON SAMPLES
FROM THE CLEMSON, SOUTH CAROLINA AREA

Sample Number	Large Foreign Material Removed by Hand Before Fractionation	Seed Cotton After Fractionation	Settling Chamber Catch		Cyclone Catch		Material Collected On Filter
			Wet	Dry	Wet	Dry	
	gms	gms	gms	gms	gms	gms	gms
Hand-Picked							
21	22.4	186.0	12.38	11.03	1.81	1.40	0.126
22	17.8	169.0	8.78	8.44	.96	.90	0.113
23	19.1	158.0	12.57	12.25	1.38	1.30	0.149
24	28.9	144.0	11.70	11.25	1.43	1.34	0.150
25	36.1	122.0	10.63	10.22	1.00	.96	0.118
26	30.0	170.0	14.23	13.76	1.21	1.14	0.175
27	29.2	176.0	15.37	15.00	1.34	1.31	0.154
28	35.6	184.0	13.08	12.70	1.15	1.08	0.138
29	18.8	150.0	13.09	12.75	1.39	1.31	0.133
30	26.4	170.0	15.23	14.81	1.00	.94	0.136
Machine-Picked							
31	5.0	166.0	4.11	3.78	.95	.86	0.080
32	5.4	153.0	5.64	5.18	.96	.87	0.061
33	2.0	196.0	6.56	6.10	.70	.63	0.063
34	5.9	141.0	5.99	5.43	.91	.82	0.096
35	3.7	159.0	7.74	7.23	.66	.59	0.072
36	10.4	169.0	9.81	9.16	.78	.70	0.062
37	3.2	162.0	6.99	6.43	.89	.81	0.079
38	11.9	156.0	8.80	8.11	.82	.75	0.083
39	13.2	134.0	17.41	16.30	.80	.73	0.068
40	13.9	145.0	15.63	14.59	1.22	1.12	0.083

TABLE 6
SHIRLEY ANALYZER AND DRYING DATA ON 19 SAMPLES OF LINT COTTON FROM THE STONEVILLE AREA

Sample Classification	Wet Sample of Lint Fed	Dried Sample of Lint Fed	Wet Samples		Dried Samples		Noncollected Waste
			Cleaned Lint	Collected Waste	Cleaned Lint	Collected Waste	
	gms	gms	gms	gms	gms	gms	% by Weight of Dried Cotton*
Hand-Picked Without Lint Cleaner							
1	100.00	92.70	94.40	2.34	89.23	2.13	1.446
2	100.00	93.17	94.53	2.60	89.29	2.37	1.621
3	100.00	92.73	94.82	2.46	90.28	2.14	0.334
4	100.00	94.17	94.88	2.54	90.74	2.25	1.253
5	100.00	92.13	94.42	2.56	89.04	2.31	0.847
Hand-Picked With Lint Cleaner							
6	100.00	93.04	96.28	1.32	91.51	1.18	0.376
7	100.00	93.62	96.14	1.28	91.78	1.14	0.748
8	100.00	92.78	96.64	.87	91.83	.83	0.129
9	100.00	93.24	96.65	1.03	91.38	.97	0.955
Machine-Picked Without Lint Cleaner							
10	100.00	94.51	93.76	4.90	88.62	4.29	1.693
11	100.00	94.55	91.73	6.33	86.86	5.53	2.285
12	100.00	94.28	94.67	3.88	89.34	3.45	1.580
13	100.00	94.61	95.00	3.63	89.71	3.21	1.786
14	100.00	94.04	93.14	4.96	88.81	4.31	0.978
Machine-Picked With Lint Cleaner							
15	100.00	94.26	94.19	4.27	89.65	3.72	0.944
16	100.00	94.48	93.28	4.91	88.83	4.30	1.429
17	100.00	94.02	94.37	3.92	89.50	3.60	0.979
18	100.00	94.50	94.71	3.26	89.58	2.90	2.138
19	100.00	94.44	94.48	3.68	90.13	3.31	1.059

*All Samples were dried for one hour at 210° F.

Applicability of Fractionator as Air Pollution Indicator

A statistical evaluation (Appendix 1) of the fractionator discharge data, Tables 4 and 5, indicates it is not possible to separate the effects of the picking method from the effects of the area from which the cotton was obtained. It is, therefore, not possible, based on fractionator data, to make a general statement that one picking method results in less air pollution material than the other, independent of the area from which the cotton was obtained. By a comparison of the mean percent air pollution material for each picking method and each area separately, it was observed that the Clemson area machine-picked cotton yielded significantly less air pollution material than did hand-picked cotton from the Clemson area, and both hand- and machine-picked cotton from the Stoneville area. The latter three did not differ significantly from each other.

Based on the fractionator data for cotton from the Stoneville area, the ranges of expected amounts of air pollution material from individual cotton samples during fractionation were estimated using statistical techniques.(2) The limits of the estimated ranges are such that the probability is less than one in twenty that not more than 5% of the individual samples will fall beyond these limits. All data were used in computing these limits, since statistical analysis failed to detect a difference between the amount of waste removed by either method of picking for cotton from the Stoneville area.

A comparison of field data (Table 3) with the limits of the estimated ranges based on the fractionator data is as follows:

Air pollution material discharged to the atmosphere from the ginning operation (Percent by weight of cotton ginned - Table 3). . . .	1.39%
Limits of estimated range of air pollution material (Percent by weight of cotton ginned after removal of seeds).	1.00% - 4.00%

It is obvious that the field test data fall within the fractionator range of air pollution materials discharged from the ginning operation; hence fractionator data may be used to predict the amount of air pollution material that would be discharged during the ginning of cotton without control equipment. Further, it is possible by statistical methods to estimate the discharge of air pollutant material (expressed as percent by weight of ginned cotton) from the fractionator data (expressed as percent by weight of cotton fiber after fractionation). The accuracy of estimation increases as the number of fractionator samples increases, e.g., based on a single fractionator sample, the estimated discharge of air pollutant material lies somewhere between 40% to 160% of the value obtained by the fractionator, whereas for 20 fractionator samples, the estimated discharge lies between 86% to 114% of the mean of the fractionator data. Intermediate values are indicated below:

No. of Fractionator Samples	Estimation Limits in Percent of Mean
1	40 - 160
5	74 - 126
10	81 - 119
20	86 - 114

Since these analyses show that the fractionator data are indicative of actual field sampling of air pollution materials discharged during the ginning process, this device could be used to evaluate on a nation-wide basis air pollution originating from cotton gins. Samples of cotton, both hand- and machine-picked, could be selected on a random basis, and sent to a central location for fractionation testing and data analysis.

(2) "Introduction to Statistical Analysis," Dixon, W. J., and Massey, F. J., Jr., p. 110, 1951, McGraw Hill.

Applicability of Shirley Analyzer as Air Pollution Indicator

Ten samples of ginned cotton (5 each hand- and machine-picked) taken just prior to passing through the lint cleaner and nine samples (5 machine- and 4 hand-picked) which had been processed through the cleaner were analyzed using the Shirley Analyzer to determine the applicability of this device for evaluating the amount of air pollutant material resulting from the lint cleaning process, Table 6. Results indicate that samples which had passed through a lint cleaner contained on the average about 70% as much particulate (noncollected waste) as did samples which had not passed through the cleaner.

Statistical evaluation of the tests performed (Appendix 2) indicates a large variation in test results, due either to sampling variation or variation inherent in the analyzer. This variation is so great that the probability is less than one in twenty that an actual difference of 30% would be detected using the Analyzer. It may be concluded then, that the Shirley Analyzer is not practical for evaluating the amount of pollution material resulting from the lint cleaning operation. By analyzing an even larger number of samples in the Shirley apparatus, it is probable that the difference of 30% noted above would be determined to be statistically significant. However, from the practical standpoint it is not desirable to employ a laboratory device requiring an excessive number of samples.

This device, however, is satisfactory for evaluating differences in pollution from the lint cleaning process due to methods of picking. Statistical analysis of this same data indicates that significantly less particulate (noncollected waste) was obtained for hand-picked cotton, i. e., about 58% of that for machine-picking. As previously noted, the analysis of fractionator data showed no significant difference between hand-picked and machine-picked cotton. There are two possible explanations for this variation. First, the Shirley Analyzer is more efficient in cleaning cotton than either the gin or fractionator, and second, before a cotton sample is placed in the fractionator, all large foreign materials, such as sticks, stems, leaves, hulls and seeds are removed by hand. In the ginning process there is a possibility that some of the above material is reduced in size, thereby creating air pollution particulates from waste normally not considered air pollution material. Since, as may be seen from the fractionator data in Tables 4 and 5, machine-picked cotton does contain more hulls than hand-picked, it is possible that the ginning operation created the difference between hand-picked and machine-picked cotton. In this event the Shirley Analyzer, which uses ginned cotton, would show this difference whereas the fractionator, which uses unginned cotton, would not.

Since this difference does not appear at present to affect the comparison of gin test data and fractionator data, further consideration will not be given to this point.

Control Equipment Investigation

Control techniques and equipment for reduction of particulate emissions must be within the economic limitation imposed by the marginal operation of the cotton ginning industry. To satisfy this economic limitation, several conditions must be met:

1. Moderate initial cost, and reasonable operation, cleaning, and maintenance costs.
2. Maximum pressure drop not to exceed about 0. 5 inches of water, so as to allow use of low cost air moving equipment with nominal power consumption.
3. Relatively simple means for cleaning and disposal of waste.
4. High collection efficiency for all particle sizes and for operation under variable flow rates and dust loadings.

After considering specifications and costs of control devices currently available, it was apparent that no standard equipment would meet all the requirements.

Because of the relatively high concentration of lint fibers in the effluent discharge, it was concluded that a control device employing

burlap (which is readily available at cotton gins) as the filter media would best satisfy all of the requirements. Burlap was chosen as the fabric because of its low cost and high porosity; hence, its low resistance and ability to maintain a high filter velocity. The burlap fibers initially act as a filtering media for the lint. Later the lint fibers collected on the burlap create a closely arranged cotton-fiber filter surface on the loosely woven coarse burlap filter cloth. Such a technique results in high efficiency filtration and still meets the required economic limitations.

To test this technique, a pilot model was constructed as shown in Figure 9. This device consisted essentially of a box, four sides of which were covered with burlap. Two high volume samplers provided the suction to pull the discharge from the gin through the inlet duct into the filter chamber, through the burlap filters, and then discharge the clean air to the atmosphere. Total discharge from the pilot filter unit was sampled using two high efficiency glass sampling filters attached to the top of the pilot unit. The filter area of this pilot device could be varied by removing a section of sheet metal and substituting a strip of filter material. By obtaining the total weight of material settled within the device and collected on the burlap, and that collected on the glass fiber sampling filters, it was possible to compute the efficiency of the pilot unit. Pressure taps were inserted on both sides of the burlap filter to indicate the pressure loss across the pilot unit.

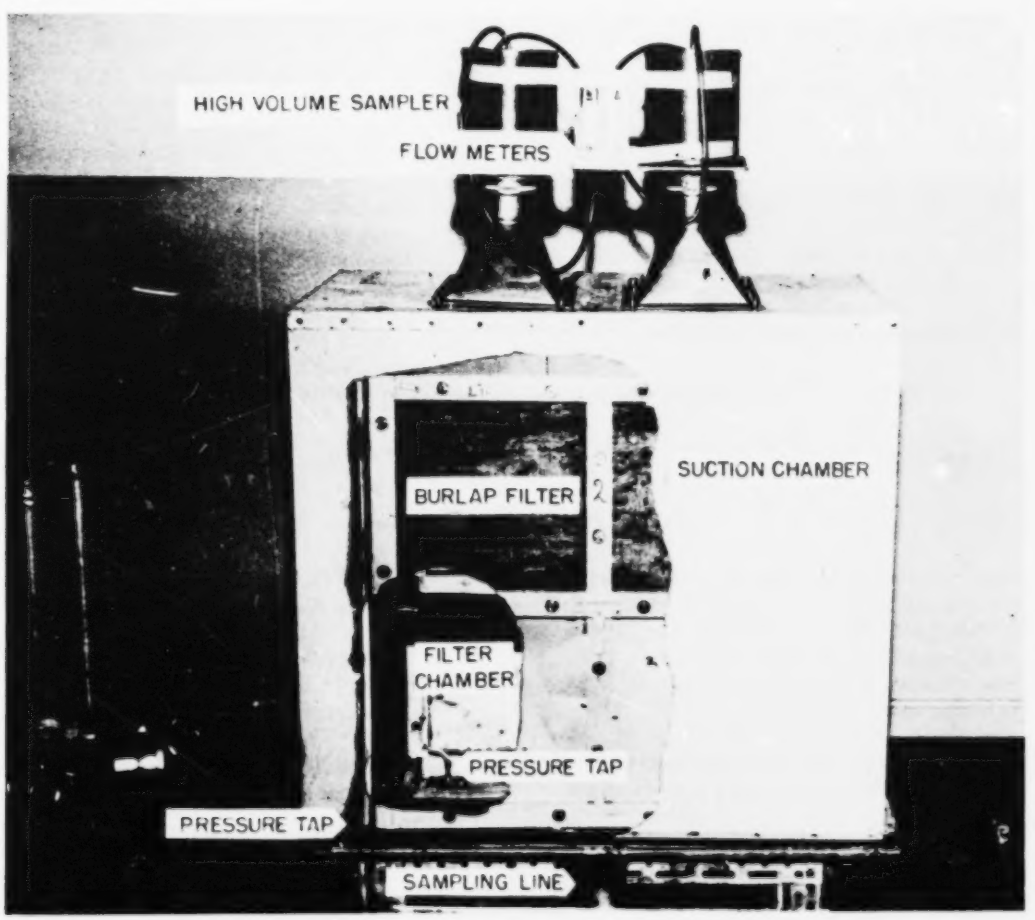


Figure 9. CONTROL DEVICE PILOT MODEL

The pilot device was tested on effluent from a commercial gin in Mississippi wherein all effluents were conducted to a single point of discharge to a dust house. Two filtration velocities were used, one at 30 ft/min. and the other at 60 ft/min. Formation of the filter matrix was excellent as shown in Figure 10. Initial pressure drop and increase in pressure drop with time were low for both filtration velocities studied. As indicated in Figure 11, the initial pressure drop for each filtration velocity was less than 0.02 inches of water and increased during a two-hour period to 0.10 inches of water for the 30 ft/min. filtration velocity and to 0.47 inches of water for the 60 ft/min. velocity.

Particulate loadings in the discharge and the total mass of particulate collected by the pilot unit are shown in Table 7. Assuming that inlet loading was uniform during all four quarters of the total sampling period, the loading during each quarter, and the collection efficiency of the unit during that quarter were calculated.

As may be seen from the results, the technique appears to be worthy of full-scale trial. Such a control unit would possess low initial cost, low pressure drop with a correspondingly low power requirement, and high collection efficiency.

It is suggested that a trial full-scale unit be designed to operate at an approximate filter velocity of 30 ft/min. Such a design would have a low pressure drop increase with time and would require cleaning only every four to eight hours. For minimal initial cost, the unit should consist of a wooden frame covered with open wire screen to support the burlap, be open sided and roofed with a sufficient overhang to protect the filters against rain. Cleaning would be done manually by entering the chamber and removing the collected lint and dust mass from the burlap.

Figure 10. BURLAP FILTER WITH LINT LOADING

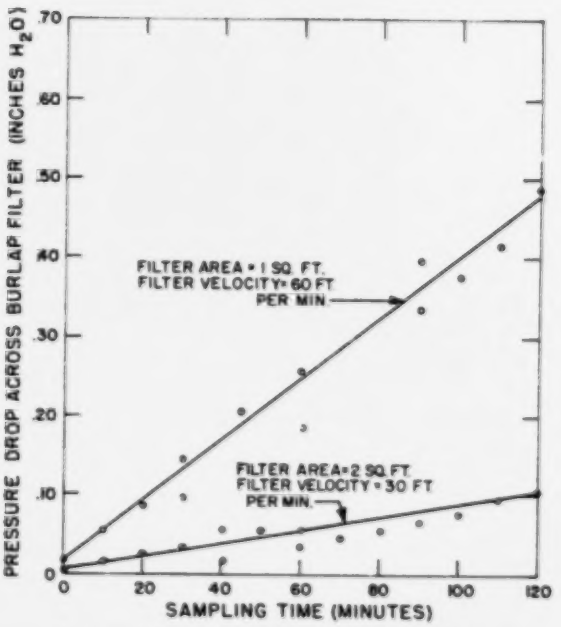


Figure 11. ANTICIPATED PRESSURE DROP DURING FILTRATION

TABLE 7
BURLAP FILTER TEST RESULTS

	TEST A Filter Area = 2 sq. ft. Filter Velocity = 30 ft./min.			TEST B Filter Area = 1 sq. ft. Filter Velocity = 60 ft./min.		
Time Interval (min.)	Loading to Settling Chamber and Burlap Filter During Time Interval (gms)	Material Collected on Glass-Fiber Filter (gms)	Efficiency of Settling Chamber and Burlap Filter	Loading to Settling Chamber and Burlap Filter During Time Interval (gms)	Material Collected on Glass-Fiber Filter (gms)	Efficiency of Settling Chamber and Burlap Filter
0 - 30	5.025	0.469	91.5%	4.45	0.280	94.1%
30 - 60	5.025	0.159	96.9%	4.45	0.068	98.5%
60 - 90	5.025	0.093	98.2%	4.45	0.053	98.8%
90 - 120	5.025	0.071	98.6%	4.45	0.025	99.4%
TOTAL	20.100	0.792	Avg = 96.2%	17.80	0.426	Avg = 97.6%

Summary

The quantity of particulate emissions from a typical cotton gin and laboratory devices for predicting such emissions have been evaluated. Although the data obtained are limited in scope, they are believed to be adequate for a general assessment of the problem. It has been shown that the standard laboratory fractionator is effective in establishing the amount of air pollution material that will be discharged to the atmosphere during ginning operations. From the limited number of areas used in this study, air pollution emissions from cotton ginning appear to be about 1-1/2% of the total weight of processed cotton. Since the gin sampled was selected as typical of such operations, this value may be assumed to show generally the order of such discharges from ginning operations.

A pilot model of a device to control particulate discharges from cotton gins was designed based on two common principles employed in control equipment; namely, gravity settling and fabric filtration. Tests in the field indicate the method to be much more efficient (96%-97% removal) than equipment presently used in ginning operations. A prototype control device based on the pilot tests is suggested as a means for economically controlling particulate discharges from ginning operations. This device should be trial tested to establish its feasibility under full-scale field conditions.

Personnel

The Engineering Research & Development Unit, Air Pollution Engineering Program, Public Health Service, carried out the field sampling and laboratory studies for this report. Messrs. C. M. Merkel, J. V. Shephard, and E. A. Harrel of Cotton Ginning Laboratories of the U. S. Department of Agriculture at Stoneville, Mississippi, made the necessary arrangements for sampling in the field and assisted in obtaining field and laboratory data.

Appendix 1

Statistical Evaluation of Cotton Gin Fractionator Data

In this evaluation, the variable X is the amount of air pollution material contained within cotton expressed as a percent of dry cotton by weight. The factor "percent dry cotton" was determined experimentally as the ratio of the weight of a 30-50 gram sample of seed cotton after drying to its weight before drying. Using data from Tables 5 and 6, a total of 40 such values of X were available.

A preliminary analysis showed that, for cotton from a given area picked by a given method, the variation between means of different samples of cotton was not significantly different from the variation within measurements obtained from replicate analysis of the same sample. This then established that sampling introduced no complications in subsequent analyses. The analysis of variance, therefore, reduced to a determination of the effect of two factors, namely area (Clemson and Stoneville) and picking method (hand and machine). The results of this analysis are given in Tables 8 and 9.

The results of the analysis of variance computations may be summarized in tabular form as follows:

TABLE 8
MEAN PERCENTAGE AIR POLLUTION VALUES (AVERAGE OF 10 SAMPLES)

	Machine-Picked Cotton		Hand-Picked Cotton	
Area	$\bar{X}$*	95% CI*	$\bar{X}$*	95% CI*
Clemson	0.54%**	0.44% - 0.64%	0.79%	0.69% - 0.89%
Stoneville	0.91%	0.81% - 1.01%	0.84%	0.74% - 0.94%
COMBINED	0.72%		0.81%	

**This value is significantly lower than the other three values, which average 0.85%.

Symbols: $\bar{X}$ - estimated mean %-air pollution (average of 10 samples)
95% CI - 95% confidence interval for true mean.

TABLE 9
ANALYSIS OF VARIANCE

	Source of Variation	Sum of Squares	Degrees of Freedom	Variance	F - Ratio
I	Between Methods of Picking (M)	0.078234	1	0.0782	I/III = 0.29 N.S.
II	Between Areas (A).	0.444577	1	0.4446	II/III = 1.66 N.S.
III	A x M Interaction	0.267813	1	0.2678	III/VI = 10.63*
IV	Between Replicate Cotton Samples.	0.232243	10	0.0232	IV/V = 0.90 N.S.
V	Between Replicate Analyses (Within Samples)	0.674013	26	0.0259	
	Total	1.696880	39		
VI	Poll IV and V	0.906256	36	0.0252	

Symbols: N.S. - not significant at 0.05 probability level.
* - significantly greater than unity at .01 probability level.

Appendix 2

Statistical Analysis of Shirley Analyzer Data

A total of nineteen 100 gram samples of ginned cotton from the Stoneville area, Table 7, nine of which had been processed through the gin lint cleaner and ten of which had not, were dried for one hour at 210° F. Each sample was weighed and then separated by the use of a Shirley Analyzer into "cleaned lint" and "collected waste" components which in turn were also weighed. "Non-collected waste" (the air pollution fraction) was expressed as a percentage of the weight of dried cotton and used as the response variable X, in the analysis described below.

The analysis of variance technique was used to evaluate the effect of two factors, namely picking method (hand and machine) and lint cleaner (i.e., whether or not the lint cleaner was used). The results of this analysis are presented in Tables 10 and 11.

TABLE 10
MEAN PERCENTAGE NON-COLLECTED WASTE VALUES

	Machine-Picked Cotton			Hand-Picked Cotton			
	n	$\bar{X}$	95% CI	n	$\bar{X}$	95% CI	Total $\bar{X}$
Lint Cleaned	5	1.31%	0.90% - 1.72%	4	0.55%	0.09% - 1.01%	0.93%*
Lint Not Cleaned	5	1.66%	1.25% - 2.08%	5	1.10%	0.69% - 1.51%	1.38%*
COMBINED	10	1.49%	1.20% - 1.78%	9	0.86%	0.55% - 1.17%	

*Ratio 0.93/1.38 = 68% (about 70%)
Symbols: n - number of samples
$\bar{X}$ - estimated mean % non-collected waste (average of n samples)
95% CI - 95% confidence interval for true mean

TABLE 11
ANALYSIS OF VARIANCE

Source of Variation	Sum of Squares	Degrees of Freedom	Variance Estimate	F - Ratio
I Between Methods of Picking (M)	1.883304	1	1.8833	I/III = 8.49**
II Lint Cleaner (L)	0.793547	1	0.7935	II/V = 3.58 N.S.
III M x L Interaction	0.188635	1	0.1886	III/V = 0.84 N.S.
IV Between Replicates (Exp. Error)	3.361341	15	0.2241	
TOTAL	6.226827	18		
V Pool III and IV	3.549976	16	0.2219	

Symbols: N.S. - not significant at .05 probability level.
** - significantly greater than unity at .01 probability level.

Appendix 3

Glossary

Boll trap - a gravity settling type device.

Condenser - a machine designed to collect ginned lint into smooth, endless "Bat".

Dust house - rather large tall structure open on top and sometimes also open on bottom. Acts as settling chamber and elutriator.

Extractor-feeder - a device which extracts burs, stems, whole leaf, and other trash from seed cotton and then feeds the cotton to the huller front gin stand.

Feed control - consists of a sealed paddle-wheel arrangement to maintain constant flow of material through the gin.

Huller Front Gin Stand - an arrangement of saws and air blasts that removes seeds, hulls, and motes from the cotton, and in addition, the gin fronts remove appreciable quantities of leaves and stems, even when elaborate cleaning and extracting processes have preceded them.

Leaf trash - small bits of leaf contained in the lint.

Lint Cleaner - a device designed primarily to remove fine leaf particles, motes, dust, sticks, and shale fragments.

Motes - a small group of fibers held together by a portion of the covering of the seed.

Pin and pepper trash - small pieces of dirt, sand, etc., that appear as pepper in the cleaned cotton.

Seed cotton - lint cotton from which the seeds have not been removed.

Separator - mechanical device which separates the carrier air stream from the carried lint. Example: wire screen with rotary rake.

Seven Cylinder Cleaner - contains seven spiked-drum cylinders which carry and "scrub" the seed cotton over wire mesh or perforated metal screens through which fine particles of leaf trash, dirt or sand, stems and small sticks are expelled from the cotton.

Six Cylinder Cleaner - similar to seven cylinder cleaner.

Stick and Bur Machine - employs a revolving saw cylinder. The teeth of the saw hold the locks of seed cotton, subject them to a carding and cleaning action as the cotton is spread across the surface of the saw cylinder, and strip them of heavy trash and burs.

Stub tower dryer - a device in which the cotton follows a tortuous path while being subjected to heated air.

Tower dryer - a longer version of the stub tower dryer.